A Social Welfare Approach in Increasing the Benefits from the Internet in Developing Countries

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***Abstract*— The paper examines the Internet usage and its market environment in developing countries under the perceived assumption that the Internet is one of the most important drivers for development. It gives an insight on processes' (both unintended and intended) implications and their effects on achieving real Internet benefits in the environments where network infrastructures are limited such as the ones found in the developing regions. A welfare based approach is proposed in which the Internet providers and end-users identify a set of objective that leads them in achieving increased benefits. Analytical model of the main characteristics in the approach is presented and eventually shown how the end user bit rate could be regulated based on the utility bounds that lead general satisfaction to all users. User satisfaction signifies delivery of expected QoS and as well as willing to pay for such services.**

***Index Terms*—welfare, benefits, fairness, Internet, user satisfaction, social-economic progress**

I. Introduction

Information and communication technology and development (ICTD) is a research area that has broadly captured the attention of the public and the academics in the last two decades. It deals with the interaction and the relations between the humans and the society in general on one side and the technology on the other side. The focus is on the computing and communication technology, including the Internet, which is seen as one of the enablers for economic and social growth. The benefit of the Internet connectivity and usage in inducing and enhancing positive social changes in basic dimensions[1]of human life is generally accepted as one of the most important drivers for development [1, 2]. Hence the success and the inevitability of the Internet in the developed world underline its proliferation and diffusion essential in less developed countries. However, sometimes these processes are being impaired by unintended and intended consequences created by the social dynamics coupled with market environments. This paper attempts to give an insight in both unintended and intended implications and their effects in the environments where network infrastructures are limited such as the ones found in the developing regions. Examples of the former (unintended) are the protocols being used and the applications being preferred, while insistences of the later (intended) are the objectives of the network providers for profit maximization.

1 Basic dimensions = economic productivity, health, education, democracy, quality of life

There are well established findings showing that protocols insensitive to fair sharing of network resources among users may lead to flow starvation and system imbalances which may further deteriorate QoS delivered. The later phenomenon causes user dissatisfaction and creates a negative perception of the Internet potential to development. In regions with limited network infrastructures the usual solution has been "more money for capacity increase". As one of the means for profit maximization this has arguably denied a large number of low-income earners (and in particular those from rural areas) from accessing the Internet and its benefits. One of the possible ways to remedy the situation is the societal approach in which the Internet providers and end-users identify a set of objective that lead to optimal benefits. The discourse reflects the present nature of the Internet hierarchical market in developing countries. The Internet market is viewed as a 3-level hierarchy, whereby the topmost level is the Network Provider (NP), middle is the Internet Service Provider (ISP) that normally sells the broadband to the third/bottom level who is the end-user. In this context the end-user can be a corporate or a residential consumer. In view of the liberalization of the telecom sector in developing countries due to the lack infrastructures, most private companies have setup their own to provide the Internet services. Therefore, our approach combines the roles of NP and ISP into one termed as the Network Service Provider (NSP). Under such a market setup, we conceptualize a societal approach based on the concept of fairness and efficiency that leads in establishing optimal point in achieving the benefits from the Internet delivered services that could foster development (a hypothetical thought that a higher penetration of Internet can influence many aspects of life: - economic productivity, health, education, democracy, etc.). We quantify the forethought benefits of NSP from the point of profit maximization. While the end-user (or the Internet consumer) benefits are modelled from utility maximization of the connectivity paid for in respect of ones preferential needs. A tradeoff analysis among these concepts through both analytical proofs and simulation experiments establishes a feasible region that guarantees delivery of selected services considered essential for fostering development. The gist for the efficiency-fairness tradeoff presented within this approach is to control the distortion of fairness concept in IP based capacity-constrained networks, which is essential in developing regions where there is deficiency in network capacity. Therefore, the goal is to parameterize tradeoff between services equality (sensitivity to service fairness) and

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throughput maximization (sensitivity to effort fairness). This address the issue of letting the users to go by there preferences in using different applications, but control the possible distortion such that the value “utility” end users get are fairly equitable. Similarly, sensitivity to effort fairness addresses the issue of throughput maximization which is the cornerstone of NSP concerns. The rest of the paper is organised as follows; Section II gives an insight on the unintended and intended consequences as a result of the Internet usage vis-à-vis its market environment from an end user social dynamics and NSP profit maximization perspectives. Section III discusses the societal approach based on the welfare methodologies that would increase the benefits for both parties (end users and NSP). Section IV, gives a conclusion of the paper and the future outlook.

II. Consequences of the Internet social dynamics vis-à-vis market enviroments

A. Unintended and Intended Consequences

In literature with respect to innovation and diffusion of technology, the term “consequences” refers to the changes that occur to an individual or to a social system as a result of adoption or rejection of a technological innovation. Consequences may take either or a combination of the following forms; desirable or undesirable, direct or indirect, and anticipated or unanticipated [3]. Whichever outcome may be, the sole goal to introduce innovations to a client system is always in good faith expecting the desirable, direct, and anticipated consequences thought it is not always the case. In lieu of the liberalization/privatization of the telecom market in most of the developing countries, among others, states anticipated the availability and affordability of the Internet access that provides the end user *(citizens)* with a global access to Internet based services. So that such a global access would open new opportunities that accrue positive benefits. While the NSP anticipated positive growth and increased income from the Internet access provision business. Generally it should be noted that unlike in developed countries where the introduction of the Internet was mainly a result of the urge to ease communication between research groups, in developing countries it was purely introduced for commercial gains. In this context the end user was seen are a consumer. Although over a decade passed now an end user can be a consumer or a producer of content or/and online services. Ideally the preferences of an end user are basically driven by several attributes in choosing the NSP. Some of the main attributes can be enumerated as cost, speed, and reliability. But the sole goal for paying the price for Internet access is to maximize its utility. In this context, the utility expresses the extent to which one can achieve the maximum benefit expected from ones’ preferred services that compensates for the expenditure made. However, it is important to note that common end users only afford to pay for share medium. The resource (i.e. the bandwidth) is shared among the several end users. As each link capacity is finite, the end users are essentially competing for the scarce resource. In most of the constrained networks, Internet traffic is predominantly characterized by a so-called best effort approach. In this approach the end user´s traffic is basically handled by the end-to-end mechanism. That is, the chains of network elements are left to handle the Internet traffic as efficiently as possible, but without any form of guarantee. Depending on the structure of the networks and their elements, instantaneous number of traffic flows, their characteristics, time of the day, etc., different end users may experience different network performance. In case a network is congested, then the anticipated network performance leads to disutilities and dissatisfaction of end users. We classify origins of such anticipated network performance in the present Internet architecture into three main domains as *consumer (end user)*, NSP, and producer (content or service provider).

1) In the consumer (end user) domain

Customer premise equipment: this is a central component in the end users environment. It has an influence on the end user’s perception on the quality of the connection as it connects to the NSP equipment. This is mainly due to hardware, software, power levels of the equipment, and the connection medium. Connection medium: it makes a difference whether the end user is connected via an Ethernet, fiber links, or wireless via a WiFi, WiMAX or Bluetooth. It addition it matters whether other people are sharing the same home network and transport their traffic simultaneously over the same links/channel. User preferences and behaviour usage: This is a component that greatly attribute to negative perceptions to end users mainly in weak infrastructure networks. An end user may intentionally or unintentionally start an application to access ones Internet based service. Depending on the application design and its nature of the underlying network transport protocol, the application may start multiple flows that results in congesting the network.

2) In the NSP domain

Offered maximum bandwidth: this is the major factor that determines end-to-end transmission rate. Besides the more direct technical factors related to the type of access network used (fixed or mobile), the actual network centric measure (packet loss, delay and response time) and the instantaneous number of users online sharing the using the same medium (network link or the same frequency space) are also of grate importance. If the NSP is more driven by profit maximization and does not offer preferential treatment to end users, then network performance may lead to different perception among end users for the same Internet access subscription, depending on time and place. Differentiation between downstream and upstream: In capacity constrained networks that tend to offer flat pricing on shared medium, NSP tend to offer high download stream capabilities at the expense of the upstream capabilities. This phenomenon ends up giving end users ford of uploading data a different perception of network performance from those one that are merely consumers.Network peering and Data routing: local NSP peer with other networks. The traffic of the end user might be going beyond the local/national network provider. Consequently the NSP has no control on delays in another network domain.

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Even if the local NSP offers a higher speed, there will be packet drops or delays at the peering router that will result in different perception of network performance to the end user. Consequently the only alternative the NSP could do is to provider another route if available. But such a route might be more expensive hence frustrating the end user too.

1) In the producer domain

The perception of the QoS offered over the Internet also depends strongly on how the servers hosting the Internet page or Internet services are dimensioned, and how they are connected to the Internet. For example a transcontinental access of a web page or Internet service is likely to deliver low QoS if not blocked to an end user in developing countries considering the anticipated network influences as discussed in the above two domains. In addition some online services are unavailable or blocked from some users because of license for use in a certain geographic area. OR the cost of the bandwidth for accompanying adverts turns not to be cost effective beyond a given number of hopes in the network or beyond a targeted region. Although some large content and service online services providers have sent up their our backbone network in different regions of the world, end users still can perceive different QoS depending on ones' last-mile link.

B. Social Dynamics and Internet Services

However taking the considerations of the market environment in the study area and the nature of the commodity in trading, we note that the Internet is not like other types of production services where producers are expected to compete for customers only through their choices of price and types of services. The Internet market has another force hereby we refer to as "*social dynamics*[1]" of the Internet, which is a consequence of the rapid technology innovations and user generation age gap. The social dynamics introduce applications on the network that have remarkable distinction of quality of services (QoS) requirements. NSPs face a challenge of providing such services that "we classify as secondly in context of development but primary in maintaining some of the clients demands/preferences despite the fact that they glossily contribute to congestion over the weak infrastructure. However, failure to meet such demands cause looses of clients to the NSP. For example we consider e-mail or/and VOIP as one of the primary class services in context of development. While Internet gaming or/and IPTV as in the secondary class. But to an NSP whose billing system is based on usage/volume-billing rather than rate-billing will gain more profits from the secondary class clients. Such an incident takes the efficiency-fairness tradeoff outside the feasible region that carter for all social class of users (haves and have-nots). Consequently the NSP goals of profit maximization on weak infrastructure are misaligned with the goals of Internet provision for development.

2 In this context "social dynamics" refer to the currently shift or move from the use of the traditional mode of services delivery to the Internet or IP based service delivery mode. On a close view, we observe that there is an explosion in voice and video applications that are constantly being used to deliver services to the end users. i.e. from the traditional telephony systems to VOIP base (e.g. Skype, messenger, etc.). TVs and Movies are constantly being watches on the Internet.

A remedy to this situation, we classify the Internet services by their traffic class. Each traffic class has a network resource demand that is reflected by its utility function. We categorize services as shown in Table 1 below based on their network resource demands and respective *priori* thought of importance/relevance to low-income earners. The Service Relevance (SR) is ranked on the scale of 1 (Highest) to 5 (lowest) that indicates the deemed importance of the service to development. Under the assumption that the user utility of each traffic class is determined only by the allocated equivalent bandwidth x_i, we introduce a new parameter $V_i = {}^{1}/_{SR_i}$ into the utility function. V_i gives the weight of a traffic class flow based on its deemed level of importance vis-à-vis other traffic classes in the network.

Further we characterize the networks from the point of striving to deliver services that meets user satisfaction levels while maintaining the tradeoffs within the feasible region. User satisfaction is a standard measure of network performance [4] and user willing to pay for the service received from microeconomics point of view.

TABLE 1
TRAFFIC CLASSIFICATION AND THEIR RELEVANCE
(Details of $f(x_i)$ see annex A)

Traffic class	Generalized mathematical formula for utility function[5]	SR	Sample application types
Stepwise	$u_1(x_1) = V_1 \cdot f(x_1)$	1	VOIP: Skype, massager
Real-time _2	$u_2(x_2) = V_2 \cdot f(x_2)$	5	IPTV, etc.
Elastic	$u_2(x_2) = V_2 \cdot f(x_2)$	1	FTP, SMTP, etc. - Best effort delivery
Rate-adaptive	$u_4(x_4) = V_4 \cdot f(x_4)$	1-3	Telnet, www, etc. - Interactive delivery
Real-time_5	$u_5(x_5) = V_5 \cdot f(x_5)$	3-5	Media streaming, On-line gaming, etc. - UDP based applications

III. A SOCIETAL APPROACH FOR INTERNET ACCESS

A. Social goal of equal utility

The goal of equal utility is that all users should get the same level of satisfaction from the network regardless of the different services in their respective traffic classes. The framework adopts the concept of *utility fair* as criteria for capacity allocation in networks [6]. A point to observe is that allotting equal utilities to all end-users across different types of services in their respective traffic classes does not mean that they were allocated equal bandwidth across their different traffic classes. Users within the same traffic class have identical utility functions, thus the utility-fair bandwidth

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allocation inside each class of user group also leads to the bandwidth-fair allocation that is within [$X_{\min\ i}$, $X_{max\ i}$] rage for each class. Refer to annex A for details. Every traffic class has a required minimum bandwidth denoted as $X_{\min\ i}$, and a maximum threshold bandwidth denoted by $X_{max\ i}$ beyond which any allocation does not benefit the user/application. Based on clear and fair decisions, the NSP normalizes the traffic taking considerations of the importance of various traffic classes and user benefits. It is done by getting a product of the scale (V_i) and traffic class utility function. Then actual utility of the end user can be quantified. We elaborate this characteristic through an example below. Demonstrating the concept of social goal of equal utility across users irrespective of the class type of service is our starting point. Consider a network consisting of a single link with a unity capacity being shared by two users s_1 and s_2. User s_1 transfers data according to an elastic application with strictly increasing and concave bandwidth utility $\mu_1(x_1)$. User s_2 transfers real-time video data with a non-concave bandwidth utility $\mu_2(x_2)$. As shown in Figure 1 below, if the link capacity is shared equally using commonly know *max-min* bandwidth allocation policy, each user gets equal bandwidth of x = 0.5units, with corresponding utility of $\mu_1(x = 0.5)$ and $\mu_2(x = 0.5)$ respectively. It is obvious that for user s_2 is not satisfied because the received bandwidth does not reach the minimum required level for video encoding.

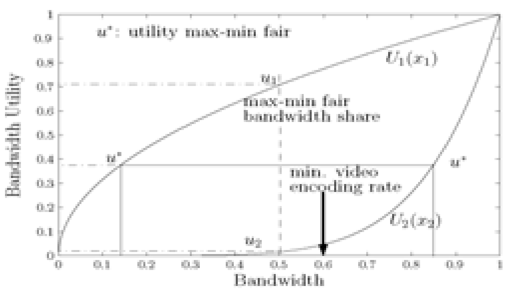

Figure 1: Utility max-min and bandwidth max-min fairness

Likewise, if the utility allocation policy ensures that the two users get equally utility, i.e. $\mu_1(x_1) = \mu_2(x_2) = \mu^*$, then accordingly both users are satisfied, hence willing to pay for the services. The latter allocation policy represents the *utility max-min* fair. The utility max-min algorithm was introduced in [7] by Cao and Zegura and its architecture in [8] by Cho and Chong. The social goal of equal utility across users is irrespective of the class type of service. A point to continue being observed is that equal utilities to the end-users across different types of services do not mean equal bandwidth to different classes or even to users within the same class type of service. As indicated in Table 1 above, all the traffic classes have a required minimum capacity/bandwidth other than the "Elastic" that can start from zero upwards. Similarly every traffic class has a maximum threshold bandwidth, beyond which any allocation does not benefit the user/application. Therefore the NSP, based on clear and fair decisions, has to normalize the traffic taking considerations of the importance of various traffic classes and user benefits. The normalization is done by getting a product of the scale determined by the NSP and traffic class function. Through this normalization then the actual utility of the end user can be quantified.

B. Utility based network modeling

We follow the works of Low and Lapsley [9], in which social utility was maximized by a bandwidth pricing algorithm. For a single link the optimization problem is as follows:

$$\max_{X_{min\_i} \le x_i \le X_{max\_i},\ i = 1, \ldots, n} \sum_{i=1}^{n} u_i(x_i);$$

$$\text{subject to } \sum_{i=1}^{n} x_i \le c$$

In such a case the maximum total utility is thought as being the sum of all utilities $u_i(x_i)$ that each user i associates with ones' allocated bandwidth x_i under link capacity constraint c. The users' utility is strictly concave and increase with the allocated bandwidth that is bounded in the rage. $< X_{\min\ i}, X_{\max\ i} >$. Beyond the utility marginal increase is almost zero and below the users' utility becomes zero. The centrality of optimization approach above and its solutions delivered through the Lagrange dual problem decomposition methods enable the network system (in this context the NSP) to establish the aggregate link price (λ) at optimal bandwidth allocation levels. Then price is passed over to the user who decides on what to purchase in view of what maximizes ones' objectives. The resulting net-utility of the user is normally formulated in the form of $u_i(x_i) - \lambda x_i$ Really this problem solving is to let the user choose what one can *afford to pay for* in lieu of ones' financial possibilities. Unlike the utility optimization form above, we propose a model that guides the user on what to take based on user preferences in lieu of services importance in context of development[1]. We assume that each service has a particular importance to its user relatively to ones' preference. In addition the cost of network resource requirements for such a service should be in the rage of users' capacity to pay. On this basis we introduce the user preference parameter in the optimization that describes the service utility (importance degree) in fostering development. Flows are differentiated based on the deemed importance degree of the services they deliver in accordance to fostering development. We introduce a scalar value V_i in the utility function that depicts the traffic class importance and the required QoS levels according to the user service preferences.

IV. Conclusions and Future Work

In this paper we have presented a social welfare approach that characterizes what would be the environment of the Internet services in view of in view to raise the benefit of the end users and NSP developing regions. Analytical model of the main characteristics in the approach is presented and eventually shown how the end user bit rate could be regulated based on the utility bounds that lead general satisfaction to all users. At individual level we shall advance our study based on the established utility levels that deem to deliver user satisfaction for a given traffic class. User satisfaction signifies

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delivery of expected QoS and as well as willing to pay for such services. Hence the focus remains on testing the actual benefits that foster a positive social change in one's basic dimensions of life from those traffic classes with high *SR*. We adopting the benefit function in [10], where individual benefits are computed and their aggregation lead us in achieving the group benefit. Here-forth referred to as the society's welfare.

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Annex A (the proofs of the equations refer to [4])

$f(x_1) = \left((\mathrm{sgn}\,(x_1 - X_{\min\_1}) + 1)/2\right);\ (x_1 \geq 0)$
$f(x_2) = (1/(1+(1/\varepsilon - 1)e^{-r_2 x_2}));\ r_2 = \left(2\ln\left(\frac{1}{\varepsilon} - 1\right)\right)/X_{\max\_2} : (X_{\min\_2} \leq x_2 \leq X_{\max\_2})$
$f(x_3) = \left(ln(x_3+1)/ln(X_{max\_3}+1)\right);\ (0 \leq x_3 \leq X_{\max\_3})$
$f(x_4) = \left(\left(ln(x_4/X_{\min\_4})/ln(X_{\max\_4}/X_{\min\_4})\right)\left((sgn\left(x_4 - X_{\min\_4}\right)+1)/2\right)\right);\ (0 \leq x_4 \leq X_{\max\_4})$
$f(x_5) = (1/(1+(1/\varepsilon - 1)e^{-r_5 x_5}));\ (X_{\min\_5} \leq x_5 \leq X_{\max\_5}, r_{5i} = \left(2\ln\left(\frac{1}{\varepsilon} - 1\right)/X_{\max\_5i}\right)$ $X_{\max\_5} = \sum_{i=1}^{n} p_{5i} X_{\max\_5i}\ ;\ r_5 = 1\Big/\sum_{i=1}^{n}(p_{5i}/r_{5i})\ ;\ (1 \leq i \leq n)$, i.e. $\exists$ n UDP flows in class 5

3 Implication: the higher the importance of a service is deemed to foster development, the lower the price for the capacity/bandwidth to deliver it to the user.

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